Surveying should be carried out in accordance with BS 5964 Building setting out and measurement[86]. A secondary 'bench-mark should be established in the vicinity of the columns and its level agreed. It should be positioned to avoid disturbance.

The gang moves the frame into a position which is acceptable to the checking engineer, using equipment such as:

- a crane
- jacks
- wire pullers (for example Tirfor)
- turnbuckles (to tension cables)
- wedges.

The gang then firmly bolts up the frame. Some local corrections may be necessary to overcome lack of fit created during the process, but the gang rarely returns to a frame once it has been aligned and bolted up.

Columns

Columns are normally located on laminated steel packs set to level (these packs can usually be left in position under the baseplate)(@. The columns can then be moved around on a horizontal plane to achieve the desired alignment. The position of a reference line, offset from the column centerline to give a clear sight, should be marked and agreed with the client's representative. This line is used either to string a piano wire or to set-up a theodolite, so that 'transverse' column positions can be adjusted. Running dimensions from the building end may be used to adjust longitudinal positions. Relying on column to column dimensions is not appropriate because of the tendency of the frame to 'grow'. Packs may be introduced between beams and columns to accommodate any (small) lack of fit.

Having correctly positioned the column bases for line and level, the columns are checked for plumb. A theodolite can be used to check against a ruler held on the outside edge of the columns, or simply to sight the outside edges themselves. Holding a ruler on the column centre lines, to eliminate the effect of rolling errors, is not generally necessary. Alternatively, a heavy plumb bob hung on a piano wire may be used. A simple damping arrangement should be adopted, such as a bucket of water into which the bob is submerged. This arrangement has the advantage over a theodolite that repeated checking does not require resetting the equipment. Optical or laser plumbing units, which are particularly useful for checking multi-storey frames, are also available. On larger sites, EDMs are increasingly used to check column alignment and plumb.

Beams

Beam levels should only be checked at points specified in the NSSS - primarily at connections to columns. These are the only points where adjustment is possible within a floor. In many cases relative levels within a floor are of more importance than absolute levels; the reasons for limiting deflections must be considered (for example to allow attachment of cladding panels). Relative levels of adjacent beams should only be checked at corresponding points, for example supports, mid-span, the tips of cantilevers. Deflection limits specified in the NSSS are appropriate when the frame is checked under the self weight of the steel alone[10].

Frame movement

It is important that all parties, including the designer, have a clear understanding of how a frame will deflect, and the limits of adjustments which can be made to the erected structure. A frame moves as adjacent bays are erected, and load application progresses. An understanding of the movement that will occur is necessary for the designer to produce a 'buildable' design, and to avoid conflict on site.

The designer should recognise that members may not be in their final position when the connections are made. Appropriate allowances for lack of fit must therefore be incorporated; for example, the connections between secondary beams and a pre-cambered primary beam should allow for the fact that the beams will not all lie in one plane under the self weight of the steel alone. Similarly, the tips of a row of cantilevers connected to different supports will vary in position depending on the degree of fixity provided by the connection. If a constant level is needed for aesthetic reasons, or to allow attachment of cladding, the designer must make provision for this when detailing the connections or cladding supports.

Frame movement must also be allowed for when the position of a part erected structure is checked on site. For example, it may be appropriate to pre-set the legs of a portal frame so that they lean in under self weight alone. Verticality will be achieved as loads are increased. The amount of pre-set is difficult to assess, since accurate prediction of deflections in general is not possible due to problems of accurately calculating base fixity, connection rigidity etc. This problem also affects the pre-cambering of beams, since the amount of pre-camber required to reduce final deflections cannot be accurately calculated.

For heavy steelwork, lining and levelling should be complete to within two bays of the erection front to avoid instability due to incomplete connections. For light steelwork this can be increased to four bays. In the case of a frame with rigid connections, it is time consuming to make any further adjustments after the joints have been fully bolted, and impossible if the joints are welded.

If appropriate, the survey results should be corrected for the effects of temperature; in most cases when surveys take place between 5°C and 15°C and no correction is necessary according to ENV 1090-1[88] .

KEY POINTS - General principles of site practice

Site practice needs to be appreciated by the designer wishing to *design for construction.* The following points summarise those aspects that are of most relevance to him.

- The steelwork contractor's erection sequence must meet main contractor's requirements.
- The steelwork contractor's erection sequence must maintain stability at all times.
- All parties, including the designer, should be realistic about the as-built frame position.